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מערכת תקשורת משוכללת אנפרא אדום ושיטה עבורה

(באנגלית)
(English)

Improved system for infrared communication and method therefor

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היום 28 בחודש October שנת 1998
This 28 of October of the year 1998

חתימת המבקש
Signature of Applicant

For the Applicants,
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FIELD OF THE INVENTION

This invention relates to a method for keeping track of objects and, in particular, to such a method for use with low consumption portable tags that may be affixed to movable objects so as to keep track of their geographic location.

BACKGROUND OF THE INVENTION

There are many situations in which it is required to keep track of movable objects so as automatically to follow their movement. For example, in an office environment wherein files may be worked on by different members of staff and are thus subjected to movement from one room to another, it is frequently necessary to keep track of their movement so that, for example, when incoming mail arrives in respect of a particular file, the file can immediately be located in an expeditious manner. One way in which this can be done is to affix to each file a portable tag which contains a memory for storing a unique identity which may be read by a suitable interrogation device located, for example, at the entry to a room so that whenever the file moves into a new room, its identity is automatically determined for onward transmission to a central tracking computer which keeps a record of each file identification and its corresponding location.

מערכת תקשורת משוכללת אנפרא אדום ושיטה עבורה

Improved system for infrared communication and method therefor

Elpas Electro-Optic Systems Ltd.

אלפז מערכות אלקטרואופטיות
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This having been said, the periodic transmission by each portable tag of its corresponding ID also results in a great amount of redundant data being transmitted. For example, if each tag transmits its ID once every 10 minutes and a file remains in a particular room for a whole week, this would result in the portable tag transmitting its ID to the same interrogation device over 1000 times per week, when only a single transmission would suffice. This, clearly, is an extravagant waste both of energy and of data transmission with the associated time overhead.

Yet a further consideration must be borne in mind when data is transmitted using optical transceivers. For example, infrared (IR) transceivers are particularly suited for the kind of task in question and require an optically transparent path unencumbered by obstacles for effective data transmission. On the other hand, if even inadvertently optical transparency is maintained between one room and an adjacent room, then there exists the risk that a file located in one room might transmit its ID to the interrogation device associated with a different, adjacent room. Such optical transparency might, for example, be the result of a dividing door between the two rooms being ajar; or owing to a window between the two rooms permitting infrared transmission therethrough.

Furthermore, in order to render such a communication system as efficient as possible, it is desirable to permit more than one portable tag to communicate with the interrogation device simultaneously. This *desideratum* clashes with the requirement to avoid collisions which, with I.R. transceivers is particularly onerous on account of the fact that it is difficult to detect collisions owing to the half-duplex communications protocol inherent in I.R. transmission.

Such an approach is acceptable when objects bearing a respective portable tag are apt to move from one location to another discretely. However, this is frequently not the case. For example, in the case of the office environment as discussed above, if a member of staff ordered several files which were brought simultaneously, then, unless each file were to be separated from the stack so as to be capable of being individually read by the interrogation device, the interrogation device would be incapable of reading all the portable tags simultaneously. On the other hand, to separate the files on entry into a new location is clearly cumbersome.

One way in which such a major drawback can be overcome is to allow the portable tag periodically to transmit its ID to the interrogation device in order that the file ID can be associated with the location of the interrogation device and then routed to the central tracking computer. This clearly overcomes the disadvantage of attempting to read many portable tags simultaneously; but imposes the price that each portable tag must constantly transmit its ID to the interrogation device. This is undesirable for several reasons. First, still to consider the office environment by way of example, if there be a large number of files in a particular room, and each file has a portable tag which transmits periodically its ID to an interrogation device associated with that room, then the volume of data which must be transmitted can be quite significant. Secondly, this, in turn, increases the risk of data collision between the IDs transmitted by different portable tags and imposes additional overheads in preventing and/or managing data collisions. Thirdly, by their very nature, the portable tags are miniature devices that are energized by a small internal power source such as a small battery. The more data which is transmitted by each portable tag, the greater is the energy consumption and the more often the battery must be replaced. This is both inconvenient and potentially very expensive when large numbers of portable tags are envisaged.

SUMMARY OF THE INVENTION

It is thus an object of the present invention to provide a method for keeping track of objects in which the drawbacks described above are significantly reduced or eliminated.

It is a particular object of the present invention to provide an improved communications protocol suitable for use with IR transceivers allowing near simultaneous two-way communication between an interrogation device and a plurality of IR transceivers.

In accordance with a broad aspect of the invention there is provided a method for keeping track of objects each having a respective unique identity and subject to movement between different locations, the method comprising the steps of:

(a) in each different location providing a location transceiver having associated therewith a location ID uniquely identifying the respective location,

(b) associating with each of the objects an object transceiver having embedded therein a respective object ID uniquely identifying the object,

(c) the location transceiver periodically transmitting its location ID for receipt by any object transceiver within a boundary associated with said location,

(d) any object transceiver receiving the location ID of a proximate location transceiver, comparing said location ID with a current location ID stored in the object transceiver corresponding to the object's current location,

(e) if the location ID received in **(d)** is not the same as the current location ID in the object transceiver, the object transceiver transmitting its object ID to the location transceiver associated with

its current location and storing the location ID of said location transceiver, and

(f) the location transceiver storing the respective object ID of each object associated therewith.

When it is sufficient for an object transceiver to transmit only its ID to the nearest location transceiver when the location ID associated therewith is different to the current location ID stored in the object transceiver, and no other information must be transmitted thereby, then unless the object moves from one location to another it can remain permanently shut down. This results in lower energy consumption and very significantly increases battery lifetime.

On the other hand, the energy consumption associated with the location transceivers is less significant because they are fixed and may therefore be permanently connected to a conventional mains electricity supply.

In order to prevent data collisions between adjacent location transceivers, a geographic area may be split into corresponding cells each representing a discrete geographical area such as, for example, a separate room each of which is allocated a separate time slice for transmitting therein its corresponding location ID. Likewise, in order to reduce the risk of data collision between different object transceivers, a plurality of separate time slots may be provided within each frame of data and each of the object transceivers may select one of the plurality of time slots randomly. Thus, providing that the ratio of the number of available time slots to the number of object transceivers which need to transmit at any given time is sufficiently high, the risk of two or more object transceivers attempting to transmit within the same time slot may be sufficiently reduced. Obviously, conventional data collision techniques requiring re-allocation of time slots and re-transmission of data may be employed in the event that, notwithstanding efforts to the contrary, two different object IDs are transmitted simultaneously.

Fig. 10a is a flow diagram showing details of a communications protocol for use by the reader during transmission of a long message from the badge to the reader;

Fig. 10b is a flow diagram showing details of a communications protocol for use by the badge during transmission of a long message from the badge to the reader;

Fig. 11a is a flow diagram showing details of a communications protocol for use by the reader during transmission of a short message from the badge to the reader; and

Fig. 11b is a flow diagram showing details of a communications protocol for use by the badge during transmission of a short message from the badge to the reader.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 shows in plan view a pictorial representation of a geographical area depicted generally as 10 comprising three separate and mutually adjacent rooms 11, 12 and 13. In each of the three rooms 11 to 13 there is mounted on the ceiling a corresponding reader 21, 22 and 23 constituting a location transceiver which allows transmission and reception of data using IR transmission. If a door (not shown) between the two rooms 11 and 12 be ajar, then an IR signal transmitted by the reader 21 so as to read all objects within the room 11 can pass through the open door into the adjacent room 12 and thus, incorrectly, read the objects therein. Likewise, the reader 22 can incorrectly read objects within the room 11 if the door between the two rooms is open. Finally, for the sake of description, there are shown objects 24, 25, 26 and 27 having associated therewith a respective portable badge (constituting an object transceiver) which can transmit data to a nearby reader as well as receiving data therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how the same may be carried out in practice, a preferred example of the communications protocol will now be described with reference to a portable identity badge, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is plan view showing pictorially a geographical area split into adjacent rooms each containing a reader and one or more portable badges for carrying out the method according to the invention;

Fig. 2 is a block diagram showing functionally a portable badge transceiver for employing the method of the invention;

Fig. 3 is a block diagram showing functionally an IR receiver for use in the readers and badges illustrated in Fig. 1;

Fig. 4 shows pictorially a message frame configuration according to a preferred communications protocol for use with the transceiver;

Figs. 5a to 5d show further details of long and short message communications protocols employed by the reader and badge;

Figs. 6a and 6b show details of the modulation scheme and reader transmission protocol;

Figs. 7a to 7e are timing diagrams showing successive frames of data of a long message transmitted by the Reader to the Badge;

Figs. 8a to 8c are timing diagrams of a data decoding circuit used in the IR receiver of the Badge;

Fig. 9a is a flow diagram showing details of a communications protocol for use by the reader during transmission of a long message from the reader to the badge;

Fig. 9b is a flow diagram showing details of a communications protocol for use by the badge during transmission of a long message from the reader to the badge;

46 block the DC level but allows data to pass through to a low noise linear amplifier 47 operating at a basic frequency 455KHz and having an output coupled to a band pass filter 48 having a bandwidth of 32KHz. The resulting carrier signal is fed to the input of a logarithmic amplifier and Received Signal Strength Indicator (RSSI) 49 allowing the signal strength to be displayed in suitable form. The signal passed by the RSSI 49 includes both data and noise and it is obviously important to filter out the noise so that the IR receiver 32 does not receive false signals. Only those signal which are determined to be genuine data signals are demodulated so as to extract the data.

To this end there is coupled a noise subtract unit 50 an output of which is fed to a capacitor 51 operating as a noise integrator whose output is fed to a first input of a summing amplifier 52. A second input of the summing amplifier 52 is connected to a variable threshold generator 53 whose threshold may be set by a variable resistor 54 external to the IR receiver 32. The output of the summing amplifier 52, corresponding to the sum of the average noise and the noise threshold, is fed to the inverting input of a comparator 55 whose non-inverting input is fed to the RSSI signal produced by the amplifier and detector 49. The output of the comparator 55 is fed to a "wake-up" signal generator 56 and to a deglitcher 57 which suppresses any pulse whose time duration is less than 25 μs and thus constitutes spurious glitches rather than actual signal data. Thus, when a signal is detected at the output of the deglitcher 57, corresponding to an actual received signal, the corresponding data associated therewith is extracted and detected.

To this end, the RSSI signal is fed to a peak detector 60 which measures its peak value and feeds it to a first, summing input of a summing amplifier 61 having a second, subtracting input connected to a variable threshold generator 62 whose threshold may be set by a variable resistor 63 external to the IR receiver 32. The output of the summing amplifier 61, corresponding to the difference between the peak value of the RSSI signal and the threshold, is fed

Fig. 2 shows a block diagram of a badge depicted generally as 30 and including an IR photodiode 31 connected to an IR receiver 32 for receiving an IR signal from one of the ceiling-mounted readers 21, 22 and 23 shown in Fig. 1. An array of LEDs 33 is connected to an IR transmitter 34 for transmitting an IR signal to one of the readers 21, 22 and 23. A micro-controller 35 is coupled to both the IR receiver 32 and the IR transmitter 34 and operates in accordance with a stored instruction set defining communications protocols allowing both long and short messages to be communicated between the badge and reader. The various communications protocols are described in detail below with particular reference to Figs. 9a to 11b of the drawings. Coupled to the micro-controller 35 is a buzzer 36 and a display 37 as well as an array of manual switches S1, S2, S3 and S4 allowing pre-programmed functions to be manually selected in accordance with the instruction set stored in the micro–controller 35. The badge circuitry is powered by a battery 38 connected to the micro-controller 35, the IR receiver 32 and the IR transmitter 34 via a power supply controller 39. The buzzer 36 and the display 37, in addition to the manual switches S1, S2, S3 and S4, allow customization of the badge for specific applications. Thus, for example, the badge can serve as a paging device for displaying a short message upon receiving a remote communication and sounding the buzzer so as to alert the owner of an awaiting message.

Fig. 3 shows in greater detail the circuitry associated with the IR receiver 32 used in the badge 30. A similar circuit is likewise employed in the ceiling-mounted IR transceivers 21, 22 and 23 shown in Fig. 1. Thus, in both cases an IR photodiode array 41 is connected to a tuned resonant circuit comprising an tuned antenna coil 42 and a capacitor 43 for applying data to the gate of a MOSFET 44. The source of the MOSFET 44 is connected to the capacitor 43 via a resistor 45 and is fed via a coupling capacitor 46 to the IR transceiver 32 having therein a memory (not shown) for allowing data to be stored therein and to be extracted, or read, therefrom. The coupling capacitor

25 and the location transceiver 22 in the same room 12 as the badge 25, the intensity of the data received from the adjoining location transceiver 21 will be reduced compared to that received by the correct location transceiver 22. This difference in signal intensity may be used in order to reject a weak signal emanating from a location transceiver in an adjoining room and thus containing the location ID of an incorrect location.

When one of the badges 25 or 26 receives the location ID #12 associated with the location transceiver 22, it compares the received location ID with the current location ID stored within its internal memory. If these are identical, this means that the ID associated with the location transceiver 22 corresponds to the current location ID within the memory of the badge and that consequently the badge has not moved since it was previously updated. In this case, unless the badges 25 or 26 need, for some reason, to transmit data other than their respective ID, their respective IR transceivers may remain silent. By such means, battery consumption may be reduced to an absolute minimum.

If, on the other hand, the location ID (#12) transmitted by the location transceiver 22 is different to that stored in the badge memory, this implies that the badge transceiver was moved into the room 12 since it was previously read. In this case, the location ID (#12) associated with the current location, i.e. the room 12, is now stored in the badge memory and the cycle is repeated.

Thus, referring now to Fig. 4, there is shown a typical frame configuration for allowing two-way wireless IR time division multiple access (TDMA) transmission between the reader and the badge. Each Reader Control Message (RCM) includes a header, a reader ID and a cellular slot ID so as to allow a particular reader to be addressed when required. The RCM further includes a badge ID in respect of four different badges which may be addressed at a corresponding one of four slots in the frame so as to provide each badge with a command whose encoded data is transmitted at the corresponding slot.

to the inverting input of a comparator 64 whose non-inverting input is fed to the RSSI signal produced by the amplifier and detector 49. The output of the comparator 64 is fed to a deglitcher 65 which suppresses any pulse whose time duration is less than 25 μs and thus constitutes spurious glitches rather than actual data. The waveforms associated with the decoded data, the RSSI and the "wake-up" signals are shown in Figs. 8a, 8b and 8c of the drawings.

Fig. 4 shows the frame configuration associated with the communications protocol according to the invention allowing up to four readers to effect bi-directional communication with a corresponding badge simultaneously. In order to explain this feature in context, reference is again made to Fig. 1 wherein each of each of the readers 21 to 23 (constituting location transceivers) has associated therewith a respective location ID so that each location ID uniquely addresses the respective location in which the location transceiver is mounted. For ease of explanation, the respective location IDs for each of the location transceivers 21, 22 and 23 will be denoted by the corresponding room number #11, #12 and #13. Each of the readers 21 to 23 periodically communicates its location ID to the badges in its area of reception so that the location of each badge may be stored therein. In order to prevent the risk of data collisions between the location transceivers 21 to 23, the communications protocol employs a data frame configuration wherein four different data slots DS1, DS2, DS3 and DS4 are allocated one to each of four different readers. Thus, each of the location transceivers 21 to 23 can transmit data only in its own time slot thus avoiding the risk of data collisions between two or more respective location transceivers in mutual line of sight with the same badge.

Each of the badges 25 and 26 receives an IR data string transmitted by the location transceiver 22 and, possibly, also by the location transceivers 21 and 23 if the adjoining door between adjacent rooms 11 and 12 or between 12 and 13 is open. However, because the distance between the location transceiver 21 in an adjacent room and the badge 25 is greater than that between the badge

such a topography, it may be shown that a minimum of four discrete time slots is sufficient to prevent data collisions.

The manner in which the time slots are allocated so as to avoid data collisions may be pre-determined either by a professional installation expert with a software interface and an exact map of the area 10; or, it may be determined automatically, on a trial-and-error basis, by the location transceivers themselves by means of listening to each other's transmissions and proceeding with the definition in a neural/serial manner.

If a message must be addressed to the badge, or received thereby, within the area covered by the specific location transceiver, each RCM may contain commands and corresponding IDs in respect of up to five different badges. The commands control the use of the rest of the frame which, as shown, is divided into four data slots. An additional time is allocated at the end of the frame for badge allocation slots.

Collision avoidance between the different location transceivers is achieved as explained above by allocating discrete time slots so that adjacent location transceivers may transmit only in their own respective time slots. Collision of data transmitted by different badges within a given area is achieved as follows. The badges do not transmit asynchronously. Instead, the location transceiver transmits the RCM and this defines the start of each frame. In each frame there are four data slots and sixteen allocation slots. If there is a message to be transmitted from the location transceiver to the badge, then the RCM transmitted to the badge includes command data for instructing the badge to receive the message in an allocated time slot. Longer messages may use more than one slot per frame (if preferred) or, alternatively, more slots in multiple frames.

A badge which needs to transmit its ID to a location transceiver, randomly selects one of the sixteen allocation slots for transmitting its ID therein. Thus, the probability of collision is reduced by 1:16 and in following

Finally, each RCM includes a CRC checksum which allows the integrity of the data received by the badge to be checked.

Following each RCM, are the four data slots depicted DSM1, DSM2, DSM3, and DSM4, respectively, within each of which a Data Slot Message (DSM) may be transmitted. Each DSM includes a header and a reader ID followed by a code which indicates whether the data corresponds to a short message or a long message. If the data corresponds to a long message, then the long data message having between 16 to 64 bytes is included within the DSM slot whereupon there is a validation check and a CRC checksum byte. If, on the other hand, the data which is to be transmitted to a particular badge corresponds to a short data message, this is provided in the form of an Allocation Slot Message (ASM) which is transmitted in one of sixteen slots following the fourth data slot (DSM4). Each ASM comprises a header and a message type followed by a short data message of up to 16 bytes. Thereafter follows the badge ID followed by a CRC.

Thus, each data cycle commences with a synchronization signal after which start synchronization signals are allocated in respect of each of the four time slots relating to the corresponding rooms 11 to 14. The four time slots may be needed (according to the four-color map theorem) in order to avoid having two areas of the same time slot and thus avoid data collisions. It will be appreciated that if the topography shown in Fig. 1 is extended to include additional rooms, then those additional rooms may likewise be allocated time slots within the same overall cycle without in any way conflicting with the four location transceivers 21 to 24 shown in Fig. 1. For example, if there were an additional room adjacent to the room 12 but remote from the room 13, then providing such a room were allocated a different time slot to the two rooms 12 and 13, there would be no danger of collision between the data transmitted by the respective location transceivers in each of the three adjacent rooms. For

transmission of a short message transmission from the badge to the reader. Thus, upon receipt of an RCM by the badge, the badge transmits a short message during a randomly allocated ASM which is received by the reader and acknowledged during the subsequent RCM transmitted thereby.

Fig. 5d shows identical data structures 80 and 81 for the reader and the badge, during the n^{th} frame and during a subsequent $(n+1)^{th}$ frame for short location messages sent by the badge to the reader, which is transmitted during one of the randomly allocated ASMs.

Figs. 6a shows the IR modulation scheme employing on-off keying (OOK) modulation of the 455KHz pulse train constituting the modulated carrier transmitted by the reader. A high logic level constituting logic "**1**" is thus represented by an absence of data whereas a low logic level (logic "**0**") results in a modulated pulse being transmitted by the reader to the badge.

Fig. 6b shows a Reader Control Message (RCM) transmitted by the reader to the badge comprising a 455KHz carrier preamble followed by a plurality of data words. A similar data slot message or allocation slot message is sent by the badge to the reader comprising a short preamble in the form of a 455KHz carrier signal followed by words of actual data.

Figs. 7a to 7e show various timing diagrams associated with the IR Receiver 32 within the badge 30. Thus, as shown in Fig. 7a, the IR Receiver 32 within the badge 30 is dormant until read by a "wake up" signal having a time duration of approximately 1 ms as shown in Fig. 7b. Each data packet transmitted by the reader to the badge comprises an initial preamble in the form of a 455KHz carrier signal having a time duration of approximately 2 ms. This wakes up the badge, whereupon as shown in Fig. 7c the power supply controller 39 becomes operative for supplying power to the IR Receiver 32 so that after a small time delay $T_{data\ delay}$ after the preamble, data transmitted by the reader is received by the badge as shown in Fig. 7d.

frames 1:16^2 etc. If the badge needs to transmit to the location transceiver a longer message including, for example, data other than the object's ID, then it initially transmits a message of type "allocation" and in the following frame it will then be instructed by the location transceiver to transmit its message in a specific time slot.

Fig. 5a shows respective data structures 70 and 71 for the reader and the badge during the nth frame as well as respective data structures 72 and 73 for the reader and the badge during a subsequent (n+1)th frame for data transmission of a long message from the reader to the badge. For the nth frame the reader transmits a RCM which is received by the badge to which it is addressed, whereby it is decoded and an acknowledgement is transmitted by the badge to the reader during a randomly allocated slot. During the next frame, the reader informs the addressed badge during which data slot message information will be transmitted. Thus, as shown in the data structures 72 and 73, message data for the addressed badge is transmitted in the third data slot DSM3. The addressed badge receives the data during this slot and transmits an acknowledge signal ACK back to the reader during a randomly allocated ASM.

Fig. 5b shows corresponding data structures 74 and 75 for the reader and the badge during the nth frame as well as respective data structures 76 and 77 for the reader and the badge during a subsequent (n+1)th frame for data transmission of a long message from the badge to the reader. Thus, as shown data structure 74, the RCM is transmitted from the reader to the badge and during the randomly allocated ASM, the badge transmits a request to the reader for Long Message Transmission. As shown by the data structure 76, the reader commands the badge at what DSM to transmit, e.g. DSM3. In this case also, correct data transmission is acknowledged by means of an ACK signal transmitted during a randomly allocated ASM.

Fig. 5c shows corresponding data structures 78 and 79 for the reader and the badge during the nth frame and during a subsequent (n+1)th frame for data

destined for a specified badge. The reader prepares an RCM for the identified badge and transmits the RCM, whereafter it awaits acknowledgement from the specified badge during one of the ASM slots. Upon receipt of the ASM, the data is decoded and, if correct, the next RCM is prepared indicating that a command destined for the identified badge will be encoded at slot K. The appropriate DSM is prepared by the reader at slot K and transmitted therein to the badge. The reader then awaits acknowledgment from the badge during the allocated slot, upon receipt of which this cycle of communication is complete. It is to be noted that if the acknowledgment by the badge to the reader indicates faulty communication, then the appropriate loop is repeated up to three times, whereafter in the absence of good data transmission, the reader informs the central computer that communication with the specified badge has failed and the reader then resumes normal operation.

Fig. 9b is a flow diagram showing the principal operating steps carried out by the badge during the transmission of long message data by the reader to the badge. Thus, initially, the badge is in standby mode until it receives an RCM from the reader. Upon receipt thereof, the RCM is decoded by the badge in order to establish the badge ID to whom the data is transmitted. If the badge ID corresponds to the ID of the receiving badge, then the receiving badge prepares an acknowledge signal ACK which is then transmitted during the randomly allocated ASM. The badge then awaits receipt of the next RCM having a destination ID which corresponds to its own ID. Upon receipt thereof, the RCM is decoded and establishes that data will be sent by the reader to the badge in slot K. The data is received at slot K of the DSM and is decoded. If the data is received intact, the badge executes whatever function is required and then prepares and acknowledge signal so as to indicate whether the required function were carried out successfully or not. The ACK signal is transmitted by the badge to the reader during a randomly allocated ASM slot and the badge returns to standby mode.

As further shown in Fig. 7a which is merely a repeat of Fig. 6b described above shown alongside the other timing diagrams for ease of comparison, actual data is transmitted from the reader to the badge following the initial preamble. Consequently, this data will reach the badge only after the badge has passed from its initial dormant state, when the battery is on standby and, as shown in Fig. 7e, the battery current is thus minimal, to its operational state, wherein battery current increases to its operational level.

Figs. 8a, 8b and 8c show timing diagrams of a data decoding circuit used in the IR receiver 32 of the Badge 30. In order to understand these diagrams, reference is again made to Fig. 3 showing a detail of the IR receiver 32. The RSSI signal shown as 90 in Fig. 8a is taken from the output of a logarithmic amplifier thus accounting for its irregular shape. The average noise derived at the output of the noise integrator is shown in Fig. 8a as a noise floor 91, whilst an upper noise limit 92 is shown as a 13.5 dB offset from the noise floor 91. The 13.5 dB offset is set by the noise threshold generator 53 and the external potentiometer 54 shown in Fig. 3. That is to say, the upper noise limit 92 defines the largest signal which could conceivably be noise: anything larger is accepted as genuine data. The upper noise limit 92 thus defines the level of the "wake up" signal 93 shown in Fig. 8b. For so long as the RSSI signal 90 is greater than the noise threshold 92, the "wake up" signal 93 is HIGH, and the data signal derived from the peak detected RSSI signal is demodulated to produce the pulse train shown as 94 in Fig. 8c. The pulse train 94 is derived by clipping the RSSI signal 90 by 6dB, this being the peak threshold set by the threshold generator 62 and the external potentiometer 63 shown in Fig. 3 and shown as 95 in Fig. 8a. The threshold 95 is subtracted from the RSSI signal 90 by the summing amplifier 61 which operates as a subtractor.

Fig. 9a is a flow diagram showing the principal operating steps carried out by the reader during the transmission of a long message to the badge. At the start of this procedure, the reader obtains from a central computer message data

subsequent RCM from the reader. Upon receipt thereof, the transmitted information is decoded and if the RCM is valid, the badge checks whether the receipt of the data previously sent by the badge to the reader has been acknowledged by the reader. If so, then a suitable signal may be output (e.g. an audible beep); the end ASM is prepared and transmitted; and the badge returns to standby mode. As before, in the absence of receipt by the badge of a suitable acknowledge signal within a predetermined number of cycles, a communications error is displayed and the badge resorts to standby mode.

Fig. 11a is a flow diagram showing the principal operating steps carried out by the reader when the badge sends a short/location message thereto. Thus, upon receipt by the reader of a badge ASM, the received data is decoded and, if valid, the short parameters are stored and the message corresponding thereto is transmitted to the central computer. Thereafter, the reader prepares the next RCM containing a suitable acknowledge signal which is then transmitted to the badge, whereupon the reader resumes normal operation.

Fig. 11b shows the corresponding flow diagram of the functions performed by the badge during transmission of a short/location message to the reader. The ASM-short message is prepared whereafter the badge awaits the RCM from the reader which should be received within a predetermined time period $t \leq T$. If the RCM is received within the correct time period, it is decoded and, if valid, the parameters encoded therein are stored. The ASM-short message is then transmitted to the reader and the badge awaits the RCM transmitted by the reader. Upon receipt thereof, the RCM is decoded and, if valid, the acknowledged message is decoded in order to verify that the short message transmitted by the badge to the reader was received correctly. In this case, no further action is required.

If, on the other hand, the acknowledged signal is negative, the badge re-transmits the short message to the reader, the whole cycle being repeated for a predetermined number of cycles e.g. 3 whereafter, if still no acknowledged

Fig. 10a is a flow diagram showing the principal operating steps carried out by the reader during the transmission of a long message from the badge to the reader. Thus, upon receipt of an ASM from the badge, the ASM is decoded and the parameters therein are stored. Thereafter, the next RCM is prepared and transmitted to the badge. The reader then awaits receipt of a DSM from the badge, upon receipt of which the data is decoded and, if intact, is stored and forwarded to the central computer. Thereafter, the next RCM is prepared acknowledging receipt of the DSM. The RCM is transmitted to the badge and receipt of the ASM transmitted by the badge is then awaited. Upon receipt of the ASM, the reader decodes the data, and, if intact, resumes normal operation.

Fig. 10b shows the corresponding flow chart relating to the principal operating steps carried out by the badge during the transmission of a long message to the reader. Initially, the ASM and DSM are prepared and the badge then awaits receipt of a RCM transmitted thereto by the reader. Upon receipt of the RCM, the data is decoded and, if intact, the parameters are stored. It will be recalled that the parameters correspond to the information transmitted by the reader to the badge indicating in which DSM subsequent data is to be transmitted by the badge to the reader. Receipt of the RCM is then acknowledged by the badge in the next ASM. The badge then awaits receipt of the next RCM, upon receipt of which the data is decoded and, if intact, this permits determination as to which data slot contains the transmitted data intended for the current badge. If no ID is found, the loop is repeated until a valid RCM is received. Again, in the absence of a valid RCM being received within a predetermined number of cycles (i.e. as shown in the figure) a communication error is provided and the badge returned to standby mode.

At this stage, assuming that data has been received intact and properly decoded, the badge is informed that it must transmit the data to the reader in DSM slot K. The required data is therefore decoded in slot K and transmitted by the badge to the reader, whereupon the badge now awaits receipt of a

In the method claims which follow, alphabetic characters used to designate claim steps are provided for convenience only and do not imply any particular order of performing the steps.

signal is correctly received, a communication error is displayed and the badge returns to standby mode. Likewise, if no RCM is received by the badge within the allotted time period T, there is again assumed to be a malfunction, whereupon a communication error is displayed and the badge resorts to standby mode. The assumption is that when a badge indicates to the reader that it wishes to transmit a short message thereto, the reader will acknowledge that request substantially immediately unless, of course, communication between the reader and the badge is broken for some reason. Therefore, lack of receipt by the badge of the RCM within this time period is interpreted as a fault in the communication between the reader and the badge.

Although the communication protocol has been described with particular reference to a single communication between the reader and a badge, it will be understood that since four DSM slots are allocated simultaneously by the reader, each badge receiving data destined therefore in only one of those four slots, there may be enacted four different communications simultaneously. This is done without effecting a corresponding increase of the RCM time because the RCM header data is constant for all four data slots and allows each of four different badges to determine in which slot data has been transmitted. This, in turn, means that each badge need only decode the data in the corresponding data slot, verify and acknowledge and this means that the data may be received by four different badges virtually simultaneously with minimum communications overhead.

It will further be appreciated that whilst the communications protocol has been described with particular reference to its implementation in a portable ID badge for maintaining track of a moveable object or person, it may equally well be employed in other applications and is certainly not restricted to such a system.

(a) in each different location providing a location transceiver having associated therewith a location ID uniquely identifying the respective location,

(b) associating with each of the objects an object transceiver having embedded therein a respective object ID uniquely identifying the object,

(c) the location transceiver periodically transmitting its location ID for receipt by any object transceiver within a boundary associated with said location,

(d) any object transceiver receiving the location ID of a proximate location transceiver, comparing said location ID with a current location ID stored in the object transceiver corresponding to the object's current location,

(e) if the location ID received in **(d)** is not the same as the current location ID in the object transceiver, the object transceiver transmitting its object ID to the location transceiver associated with its current location and storing the location ID of said location transceiver, and

(f) the location transceiver storing the respective object ID of each object associated therewith.

3. The method according to Claim 1, further including the step of:

(g) all of the location transceivers transmitting the respective object IDs of all objects associated therewith to a central tracking receiver for maintaining a record of all location IDs and associated object IDs.

4. The method according to Claim 1 or 2, wherein a signal transmitted by a location transceiver is able to travel beyond the boundary associated with the location transceiver and step (d) includes the further step of:

CLAIMS:

1. A method for effecting bi-directional IR data communication between a reader and a plurality N of portable objects each having associated therewith a respective object transceiver which is initially dormant and has embedded therein a respective object ID uniquely identifying the object, the method comprising the steps of:

at the reader:

transmitting to an object transceiver a preamble containing said object ID for awaking the object transceiver from its initially dormant state,

transmitting a Reader Control Message (RCM) followed by a frame of message data, said RCM including a header, a reader ID so as to allow the reader to be addressed when required and further including each of said object IDs for addressing the respective object transceiver at a corresponding one of N data slots in the frame so as to provide each object transceiver with a command whose encoded data is transmitted at the corresponding slot,

said message data including a header and said reader ID followed by a code which indicates whether the data corresponds to a short message or a long message,

said long message having up to a predetermined number of bytes included within the data slot, and

said short message comprising a header and a message type followed by a short data message of up to a predetermined number of bytes data which is received in a randomly allocated slot following the N^{th} data slot; and

the badge transmitting to the reader in one of said randomly allocated slots.

2. A method for keeping tack of objects each having a respective unique identity and subject to movement between different locations, the method comprising the steps of:

9. The method according to any one of the preceding Claims, wherein the object and location transceivers are IR transceivers.

10. An object transceiver which is programmed to carry out the method according to any one of Claims 1 to 8.

11. A location transceiver which is programmed to carry out the method according to any one of Claims 1 to 8.

12. A system comprising at least one location transceiver and at least one object transceiver which are programmed to carry out the method according to any one of Claims 1 to 8.

For the Applicants,
REINHOLD COHN AND PARTNERS
By:

(d1) allocating to potentially conflicting location transceivers discrete time slots for transmitting their respective location IDs so that no more than one location ID can be received at any given time by an object transceiver.

5. The method according to Claim 3, wherein each of the locations is a room and the boundary is a wall separating the room from an adjacent room and step (d1) comprises the steps of:

(a) allocating four discrete time slots per data communication steam, and

(b) apportioning a respective one of said time slots to each of up to four adjacent rooms so that the respective location transceiver in each of the adjacent rooms transmits during its time slot only.

6. The method according to Claim 4, wherein:

the data communication steam includes a plurality of object transceiver time slots each for allowing one of the object transceivers to transmit its respective object ID, and

each of the object transceivers randomly selects one of the object transceiver time slots for transmitting data therein.

7. The method according to any one of the preceding Claims, wherein if the location ID received by an object transceiver is the same as the current location ID stored therein, the object transceiver maintains silence so as to minimize energy consumption.

8. The method according to any one of Claims 1 to 5, wherein the object transceivers are adapted to transmit an object data stream containing the respective object ID and an additional message, there being further included the step of:

each of the object transceivers randomly selecting additional object transceiver time slots, as required, to completely transmit said object data stream.

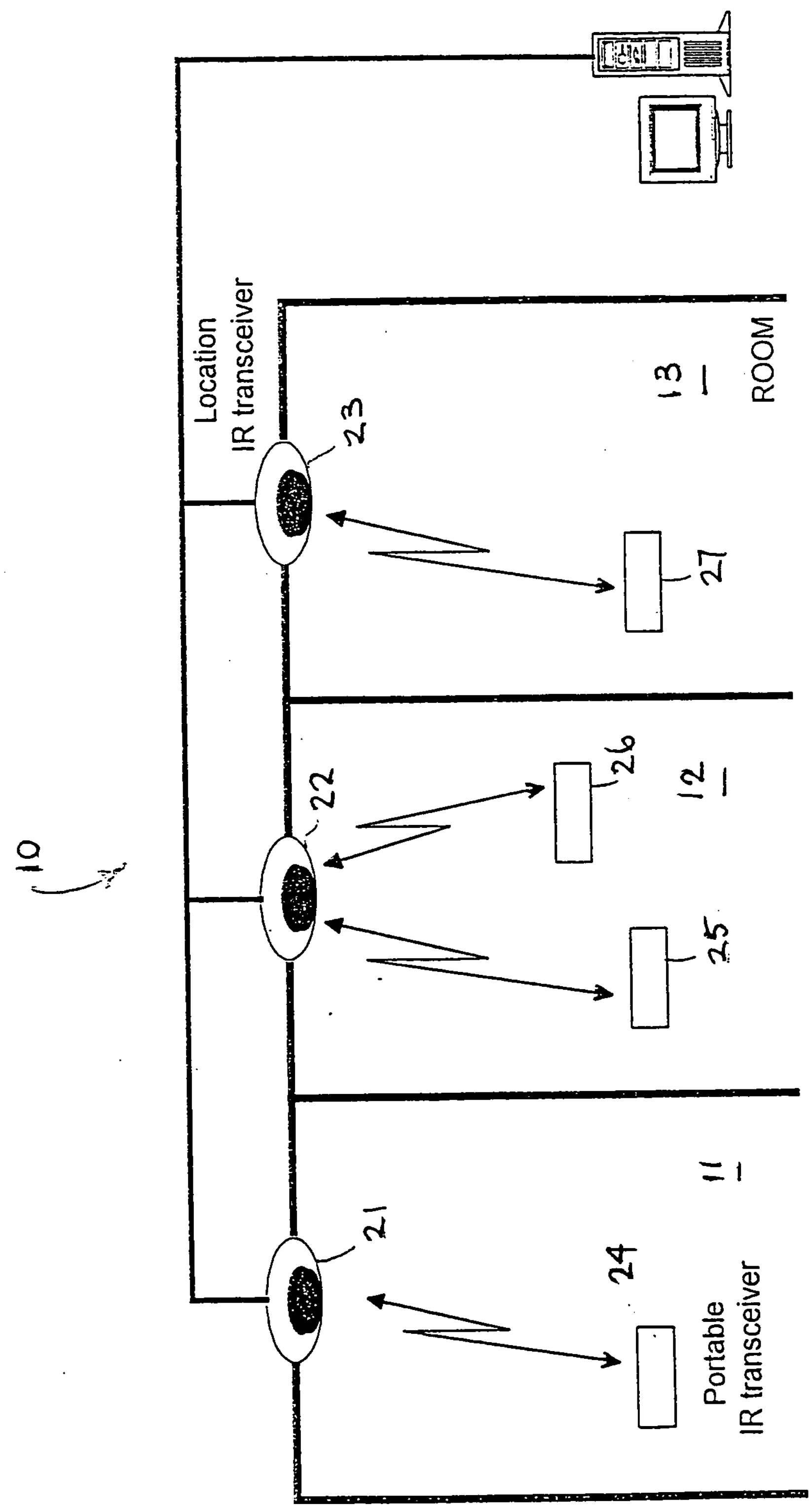

Fig. 1: Portable IR transceivers and Location IR transceivers

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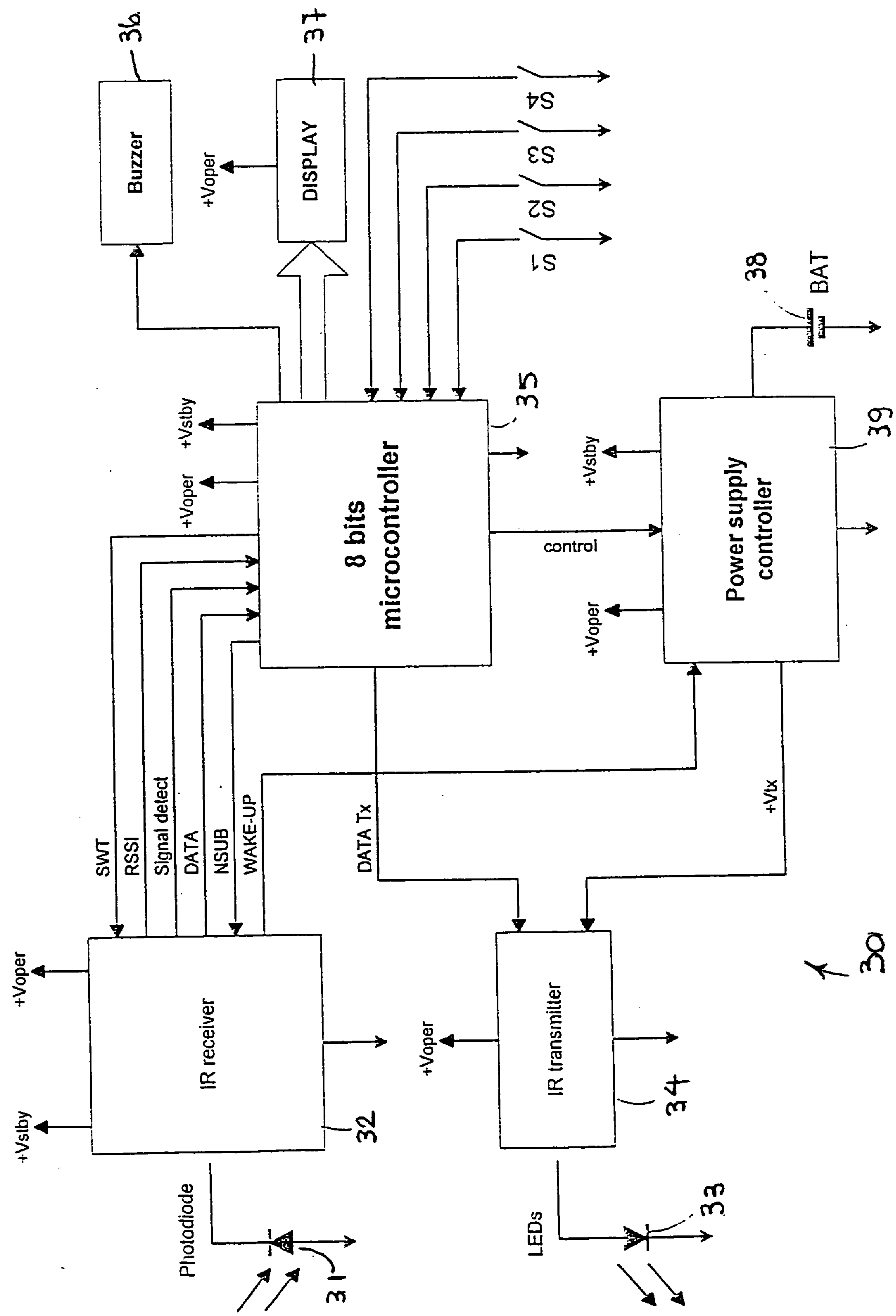

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Fig. 2 : IR Portable Badge - Block Diagram

RCM :

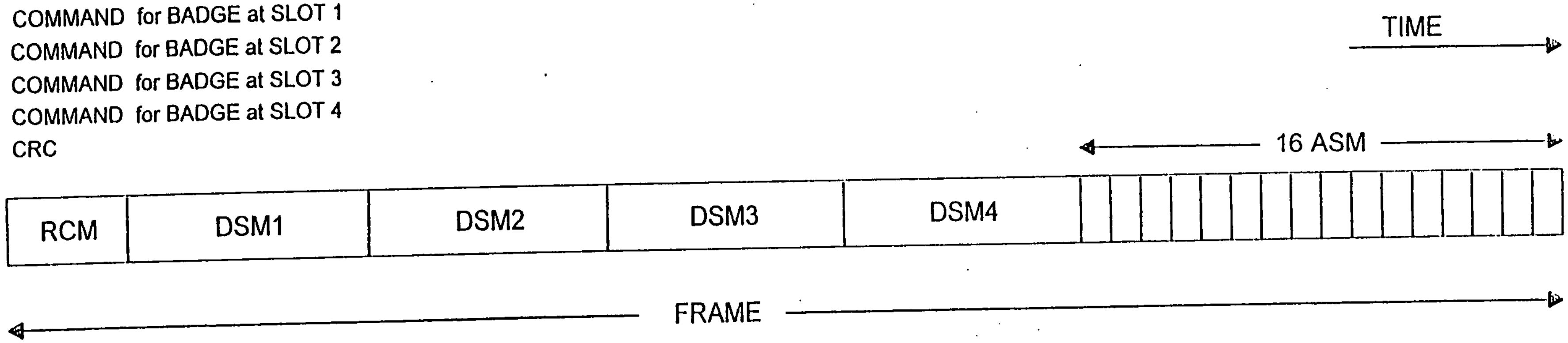
HEADER
READER ID
CELLULAR SLOT ID
BADGE ID # at SLOT 1
BADGE ID # at SLOT 2
BADGE ID # at SLOT 3
BADGE ID # at SLOT 4
COMMAND for BADGE at SLOT 1
COMMAND for BADGE at SLOT 2
COMMAND for BADGE at SLOT 3
COMMAND for BADGE at SLOT 4
CRC

DSM (each of 4):

HEADER
READER ID
DSM LENG TH
LONG DATA MESSAGE (16-64 bytes)
VALIDATION CHECK
CRC

ASM (each of 16):

HEADER
MESSAGE TYPE
SHORT DATA MESSAGE
BADGE ID
CRC



RCM - Reader Control Message

DSM - Data Slot Message

ASM - Allocation Slot Message

Fig 4: Two - Way Wireless IR TDMA Reserved ALOHA Protocol - Frame Configuration

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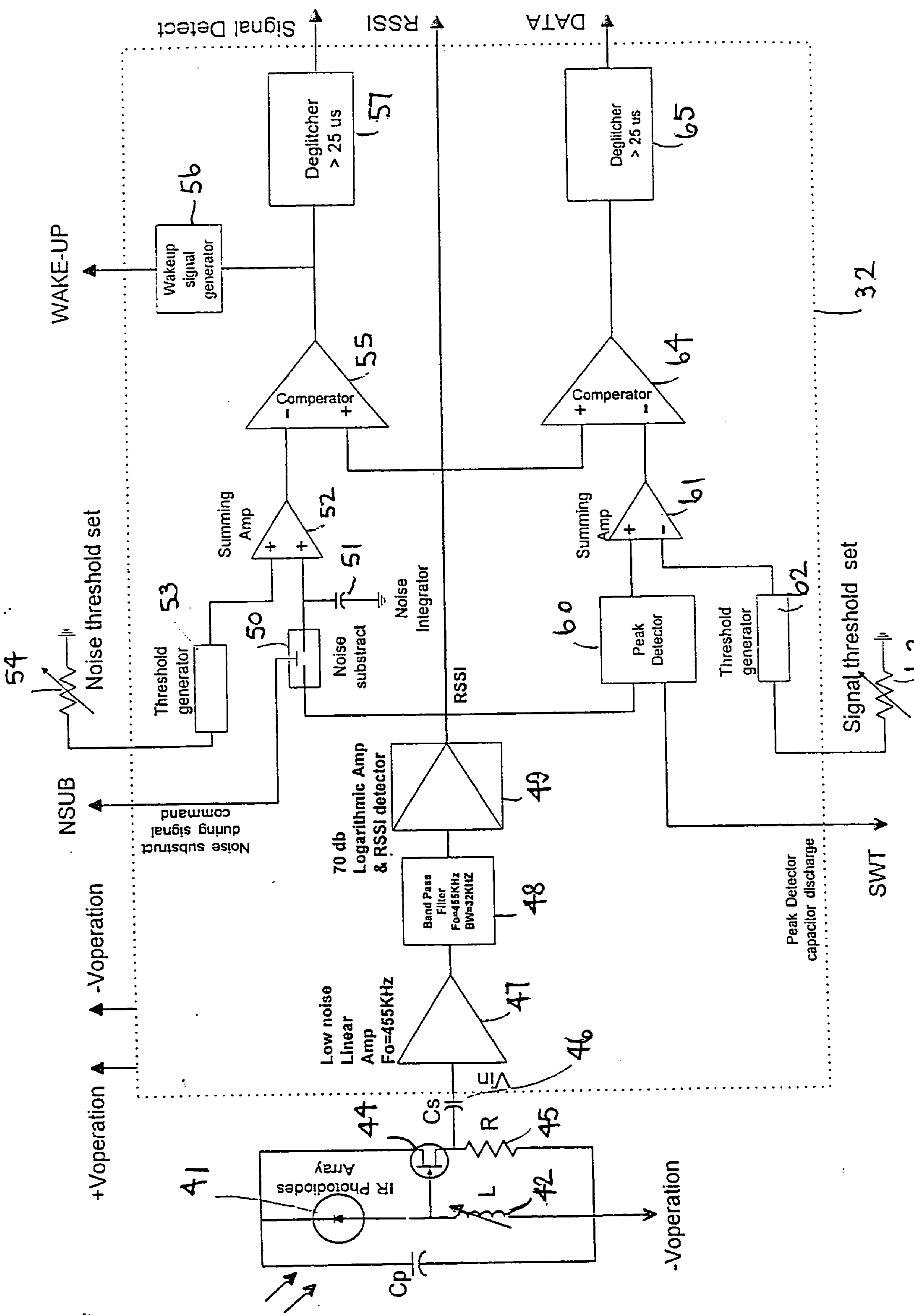

Fig. 3: Block diagram of IR receiver

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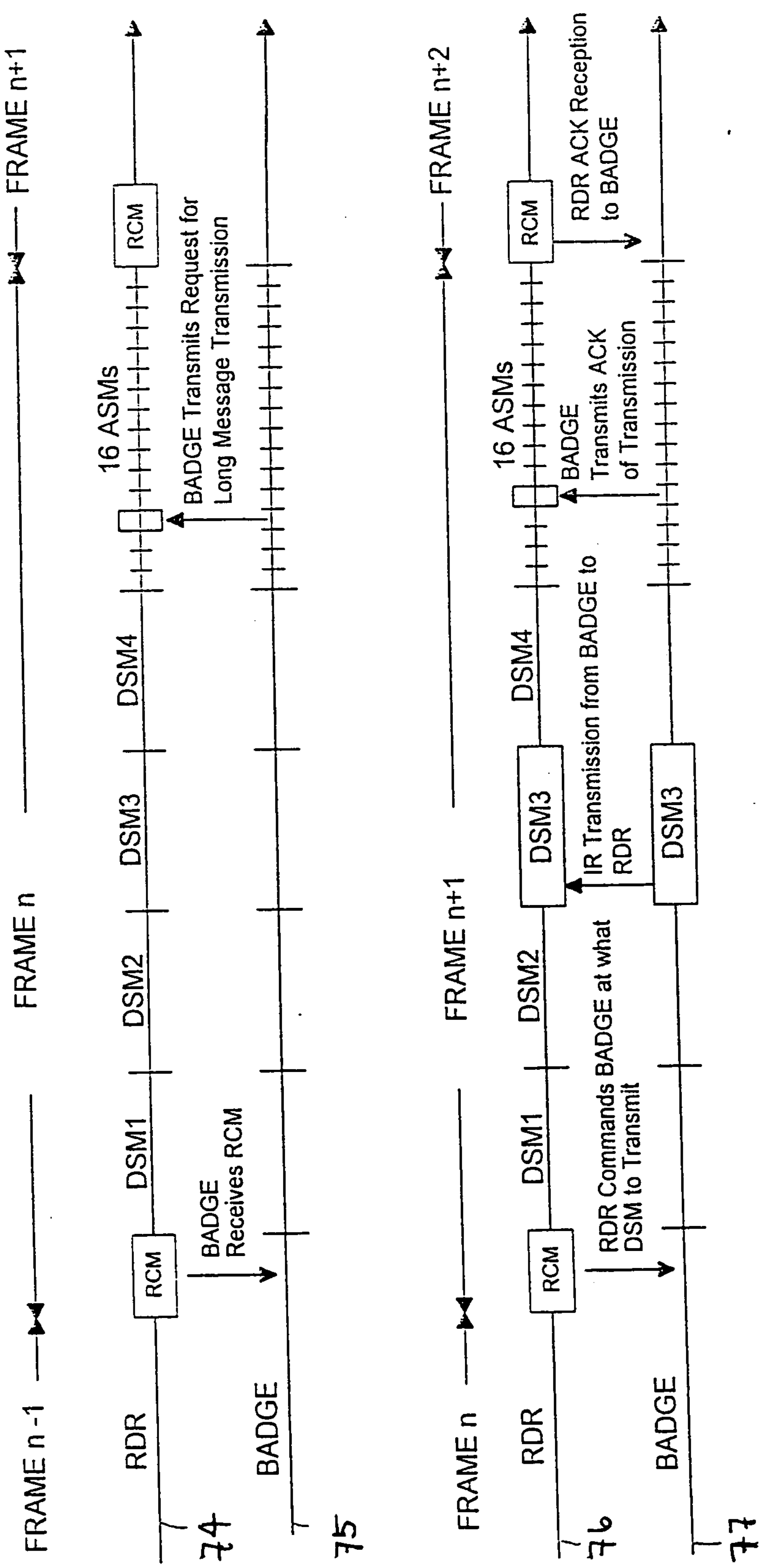

Fig 5b: BADGE to RDR Long Message Transmission Protocol

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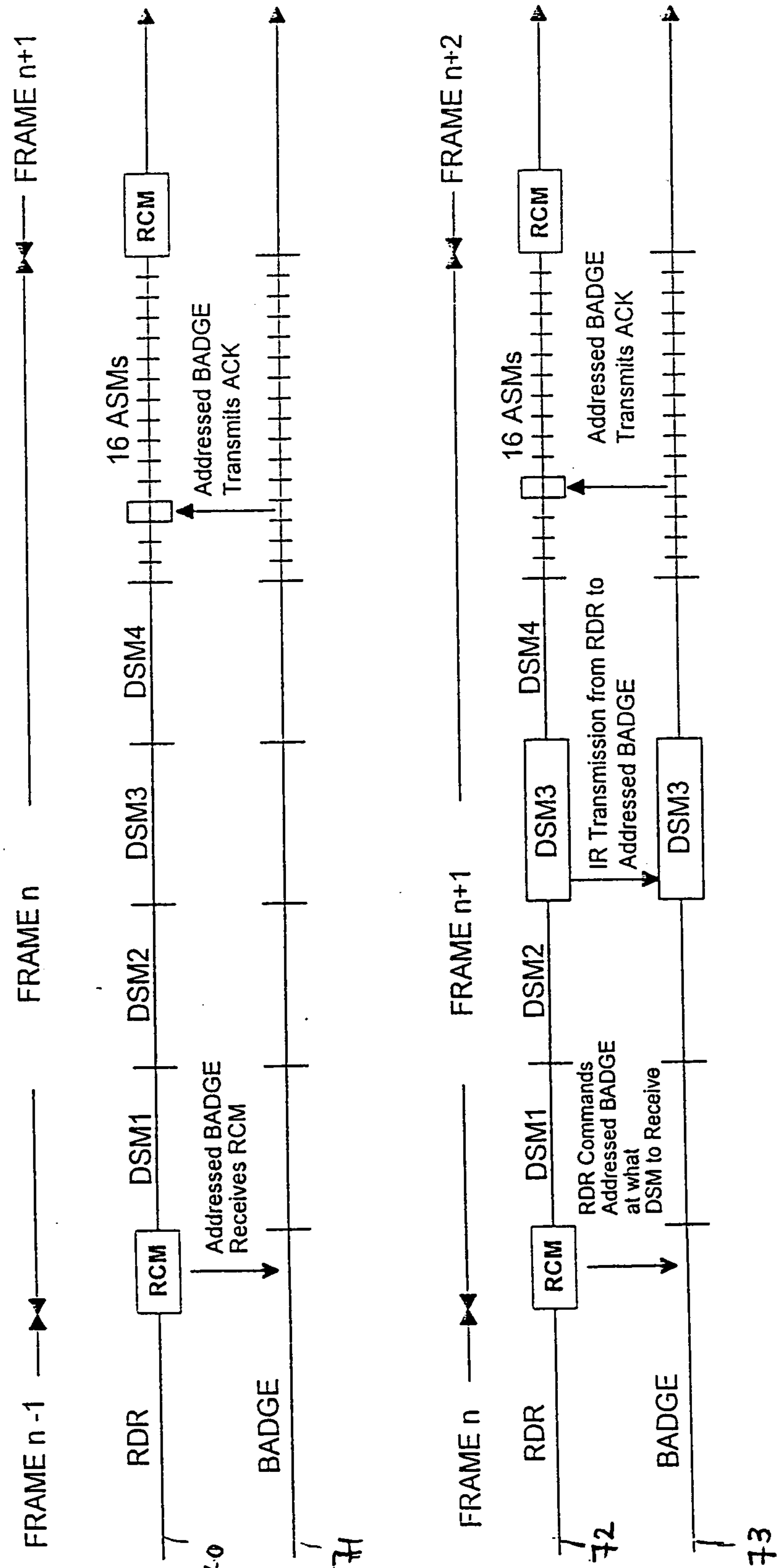

Fig 5a: RDR to BADGE Long Message Transmission Protocol

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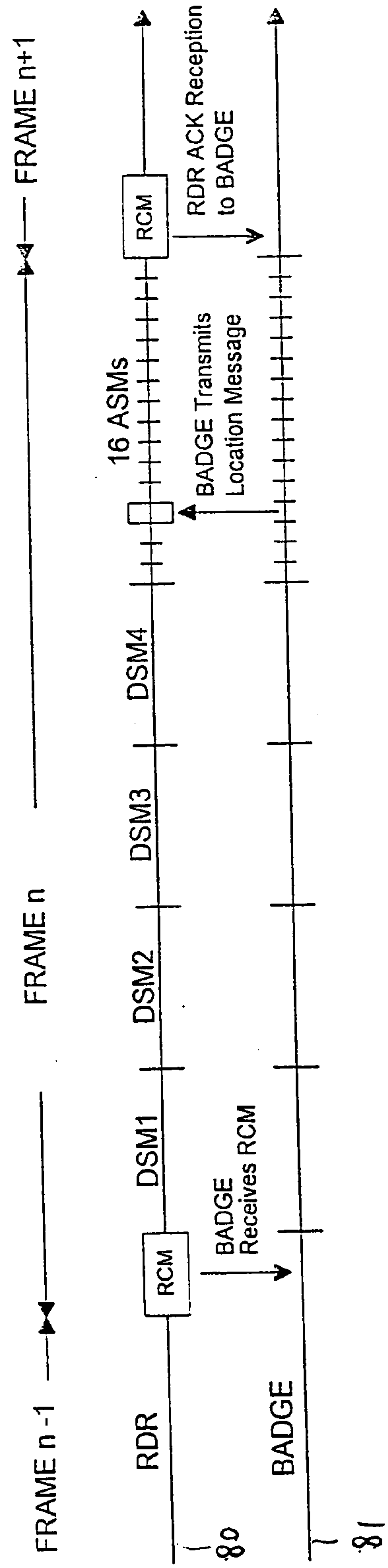

Fig 5d: BADGE to RDR Location Message Transmission Protocol

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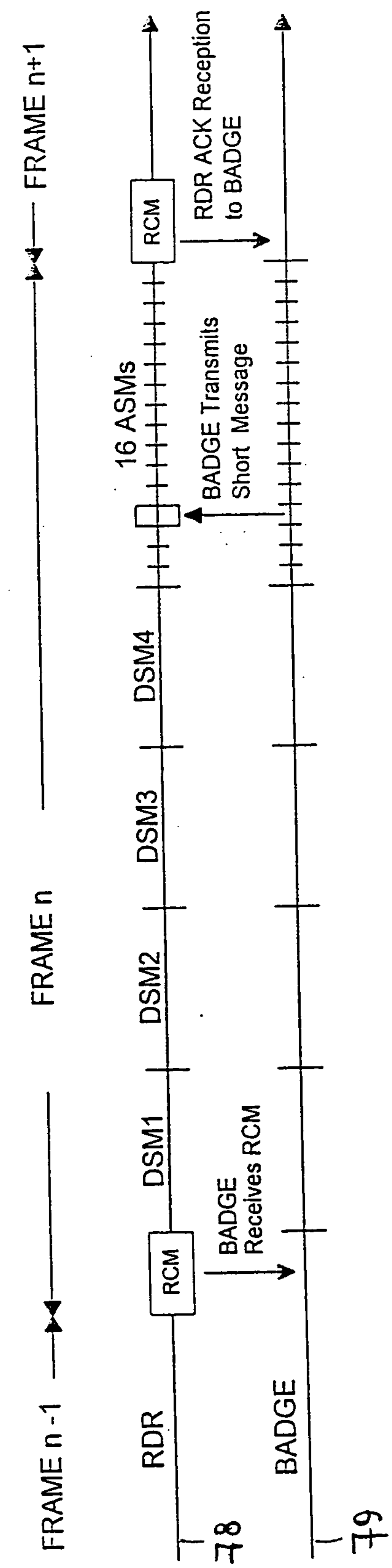

Fig 5c: BADGE to RDR Short Message Transmission Protocol

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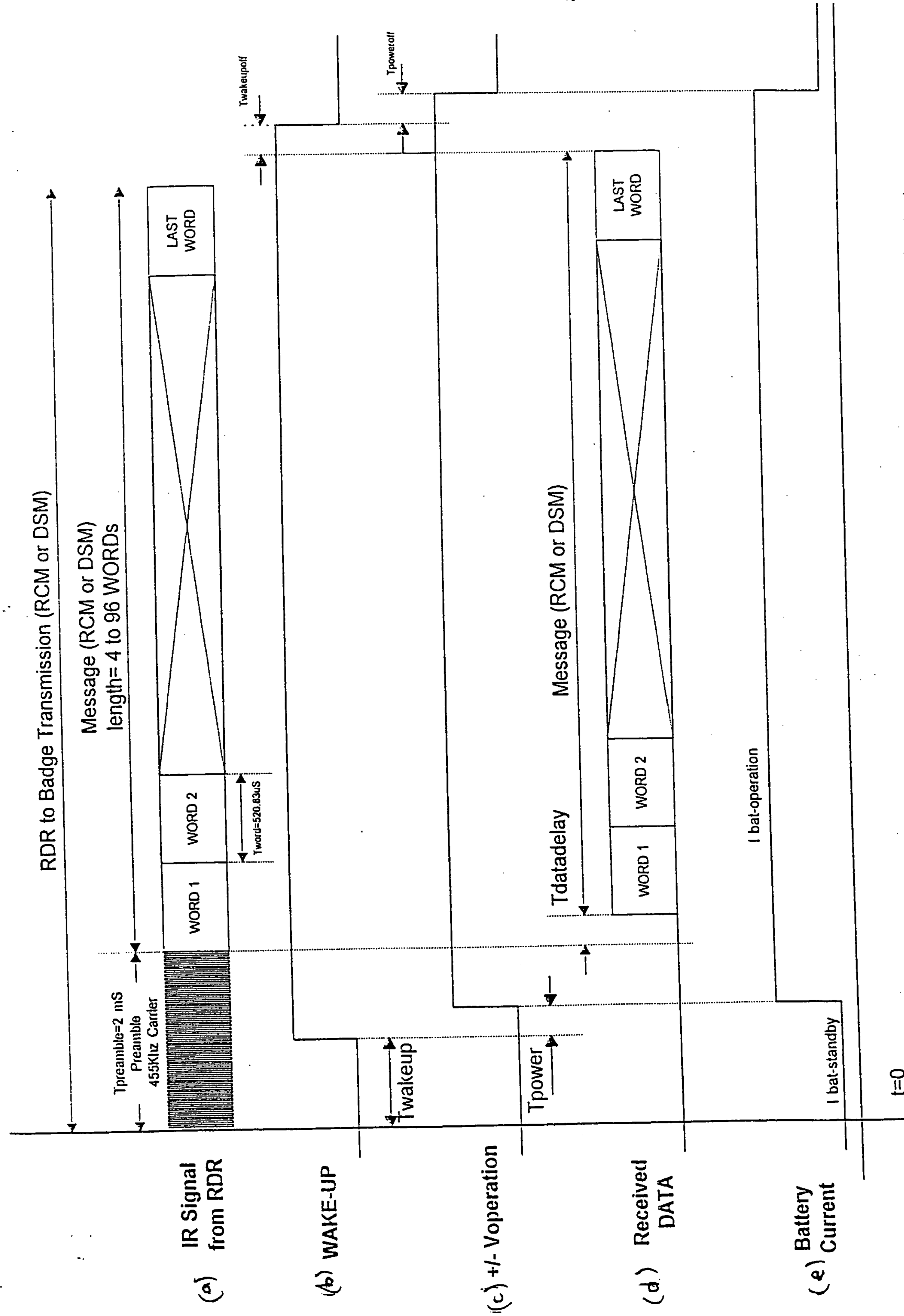

Fig 7: Timing Diagram of BADGE IR Receiver Operation

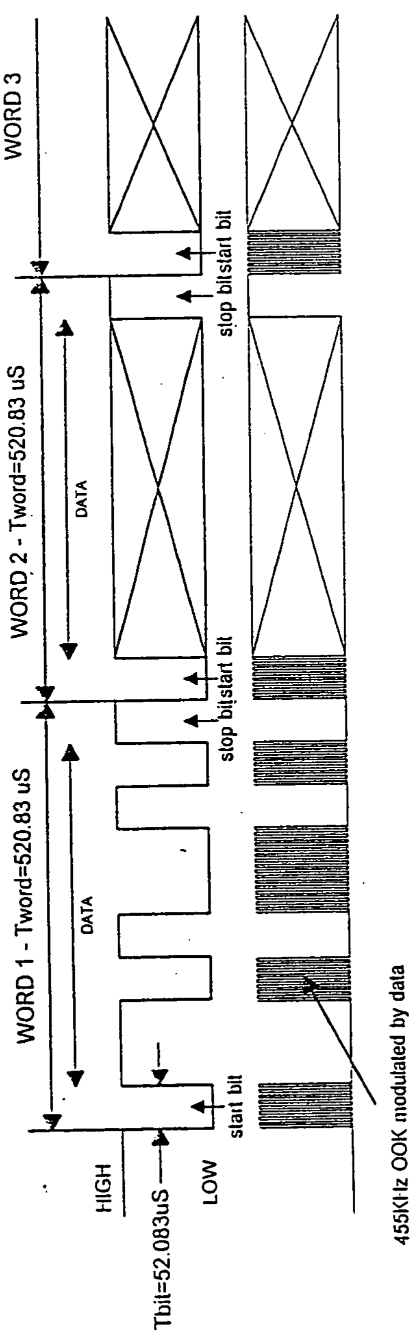

Fig 6a : IR Modulation Scheme (ASK OOK)

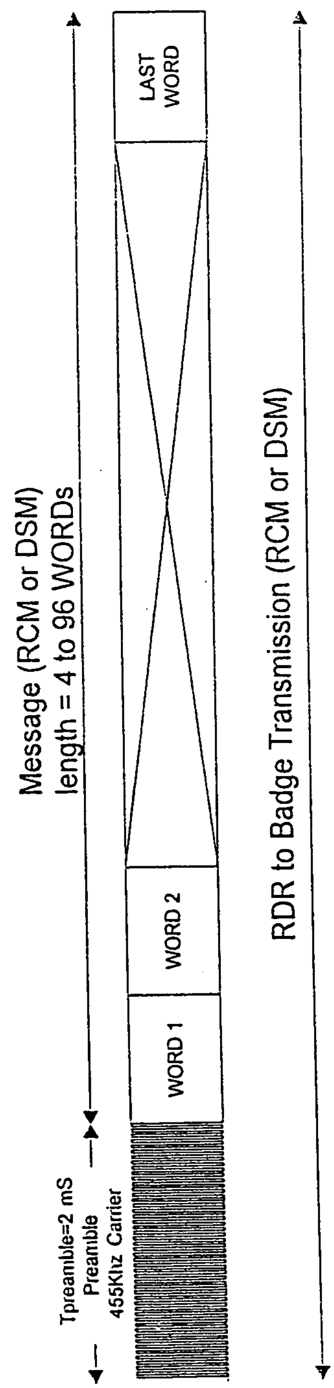

Fig 6b: RDR IR Transmission Protocol

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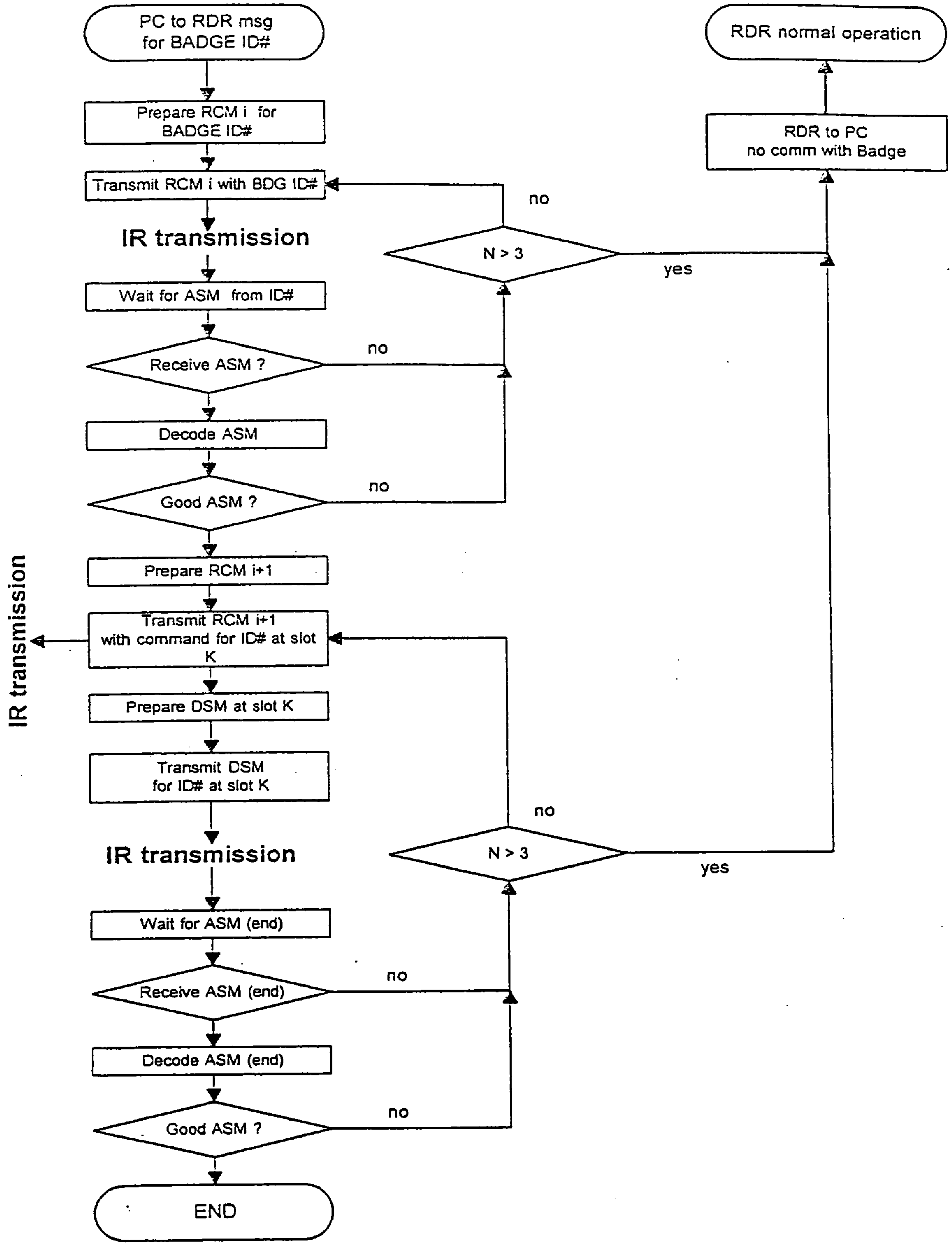

Fig 9a: RDR to BADGE Long Message Transmission Protocol
RDR Flow Chart

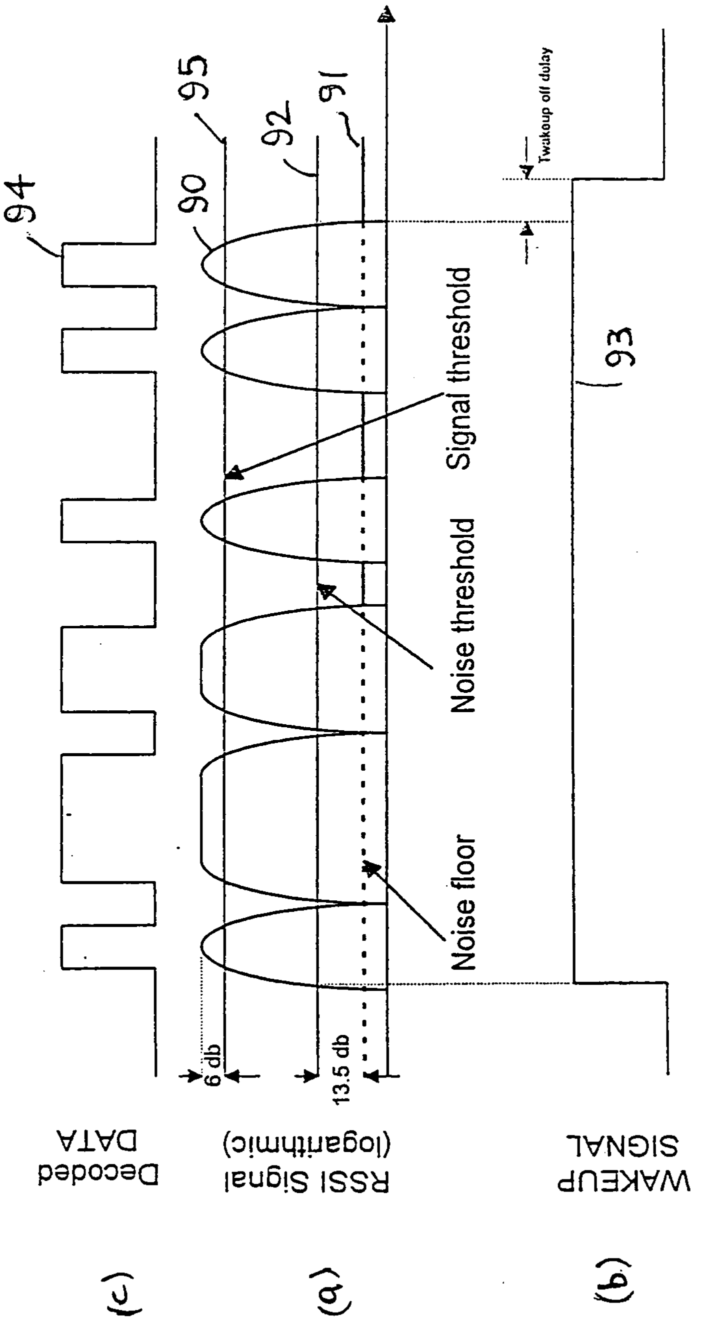

Fig 8: Timing Diagram of the DATA Decoding Circuit

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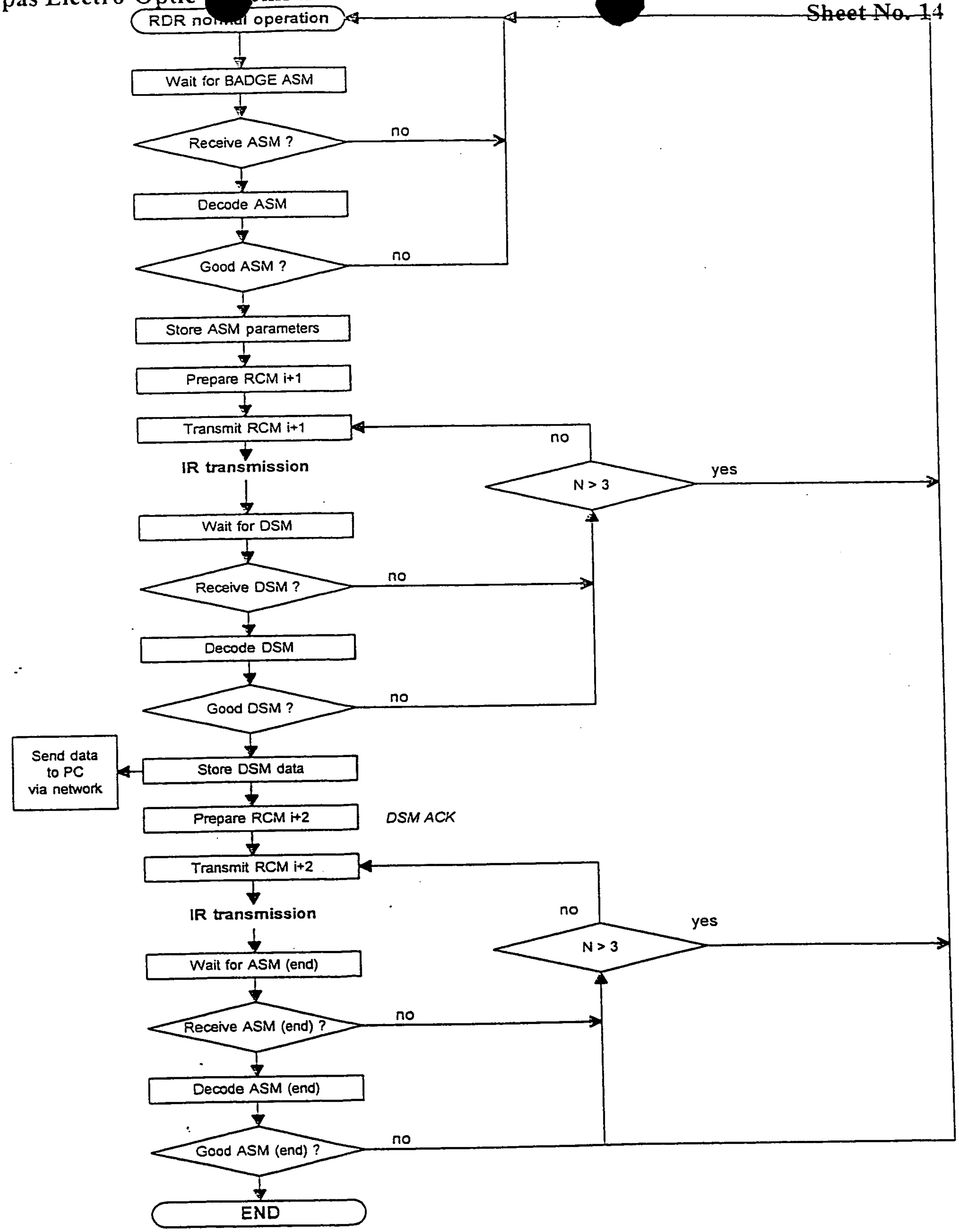

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Fig 10a: Badge to RDR Long Message Transmission Protocol
RDR Flow Chart

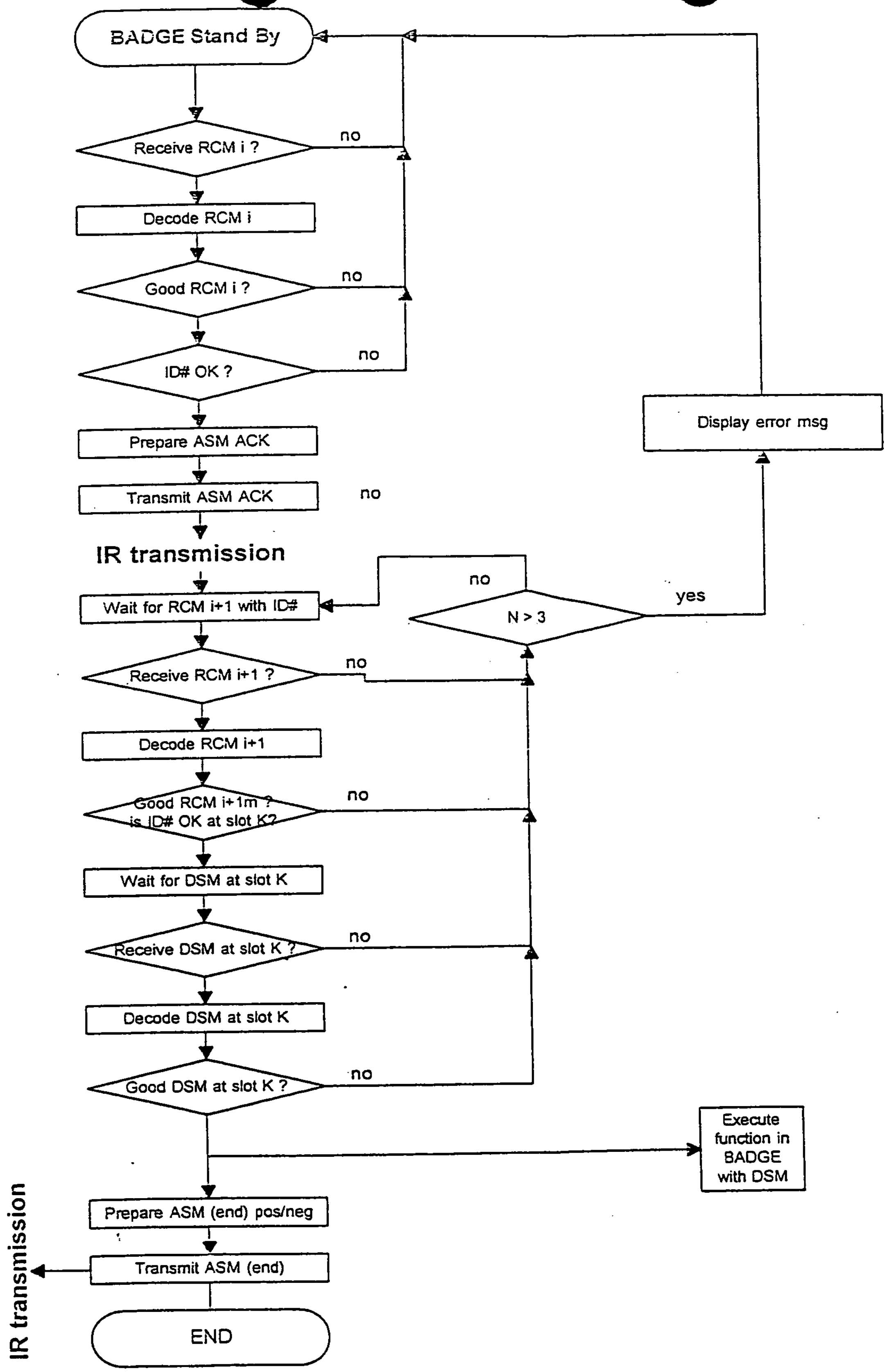

Fig 9b: RDR to BADGE Long Message Transmission Protocol
BADGE Flow Chart

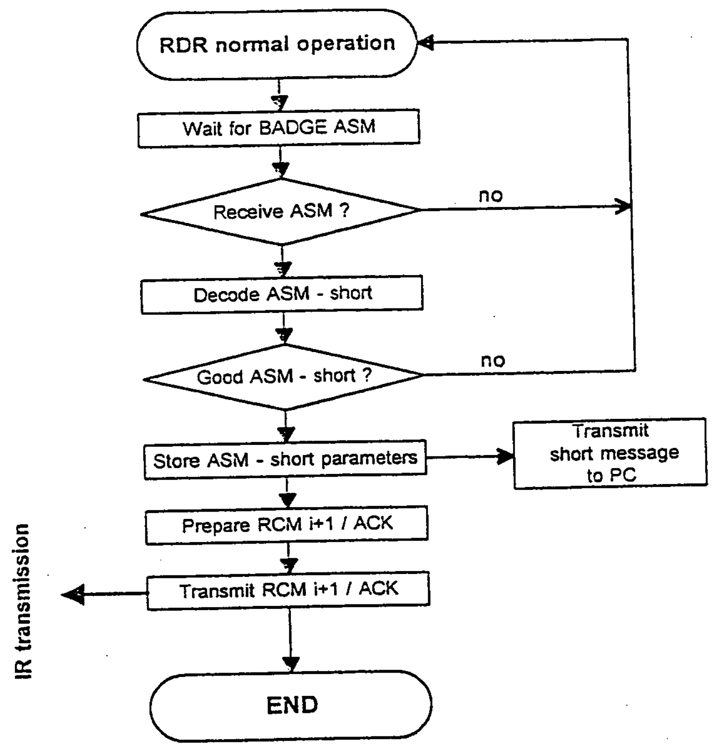

Fig 11a: Badge to RDR Short / Location Message Transmission Protocol
RDR Flow Chart

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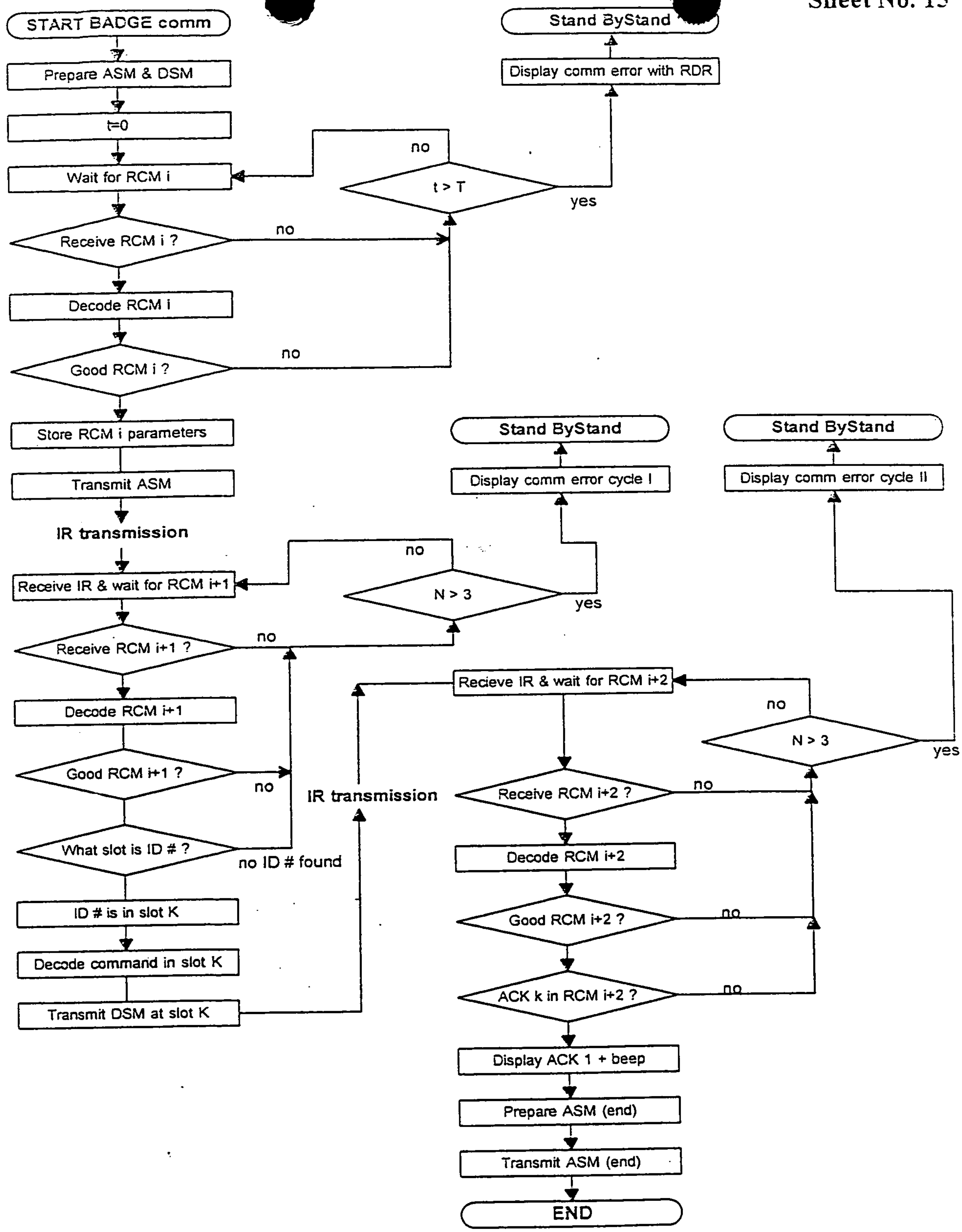

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Fig 10b: Badge to RDR Long Message Transmission Protocol
BADGE Flow Chart

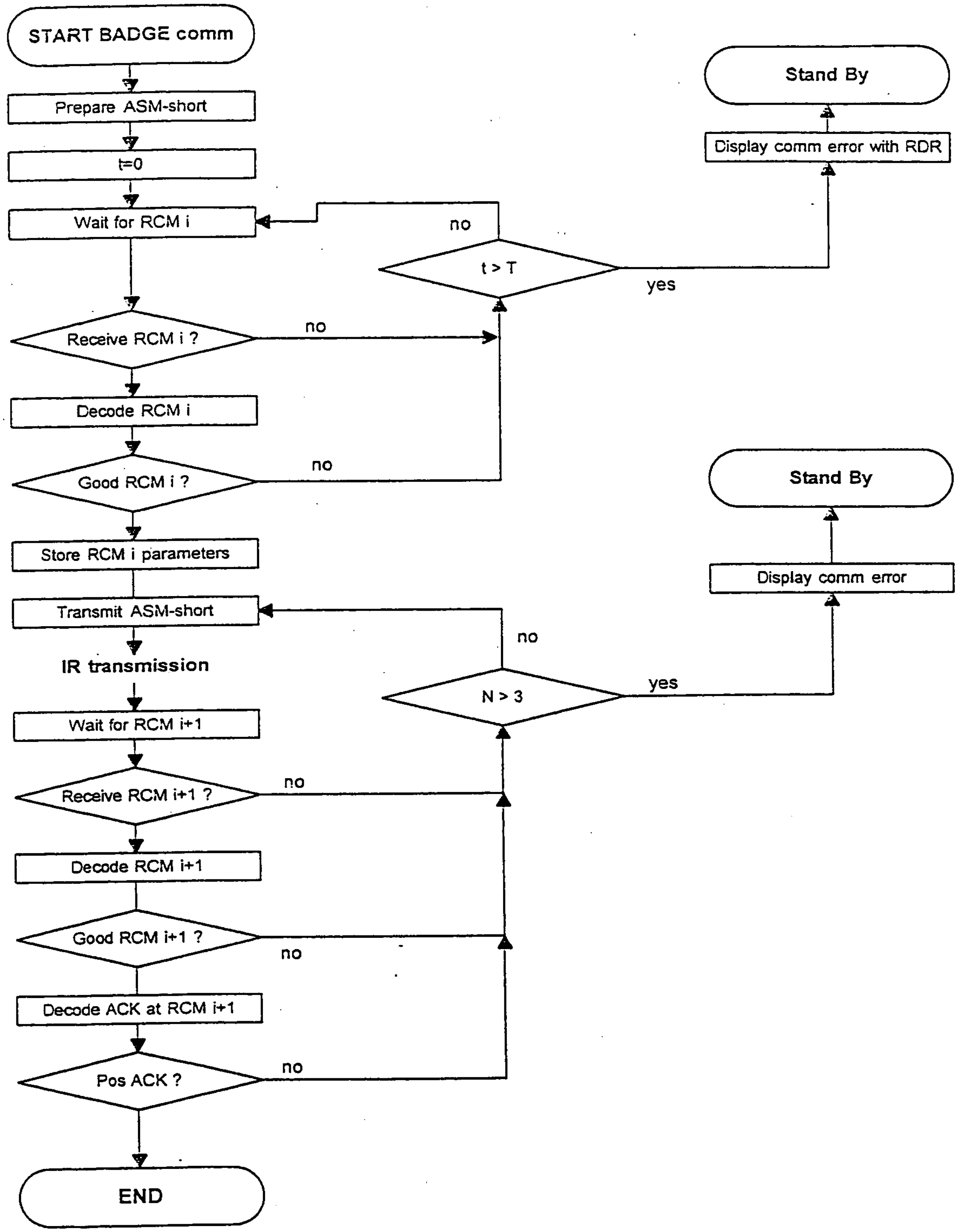

Fig 11b: Badge to RDR Short / Location Message Transmission Protocol
BADGE Flow Chart

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